THE SIMULATION OF WATER DEMAND AND SUPPLY SCENARIOS BY USING THE SYSTEM DYNAMICS TOOL

Jan Ming-Young and Huang Ming-Yang, Dept. Civil and Ecological Engineering., I-Shou University, Taiwan
Cheng Chang-Chi, Dept. of Property Management, Chien-Hsin University of Science and Technology, Taiwan

ICID2015
26th ERC & 66th IEC

Introduction

Less rainfall made all the water supply system out of control at the small islands around Taiwan. Since drought occurs frequently during these years, water management agencies were forced to find some solution or measurement to overcome the extreme event. If theses drought events and measurements can be simulated for a reasonable process, then the water management agencies can make some water saving decision in advance.

Penghu(Fig-1) islands in Taiwan strait is suffered from water shortage due to its natural properties and the rapid increased in sightseeing developments. This study intends to find possible approaches to solve water shortage problem through the concept of dynamic system analysis. Water shortage problem concerns demand and supply systems. Demand system depends on the population growth, water usage per capital per day and amount of tourists for every year and water price is used as a strategy for decreasing water using. Expanding desalination plant, building new desalination plant and renewable water implementation are considered as the strategies of supply system. This study makes all the possible combinations among these strategies and tries to obtain the performance of combination for decision making.

Methods

This paper intends to use the system dynamics to establish possible conditions on water shortage. Water shortage means the status of less water or more demands for an existing water supply system. Demand of water depends on the population variation, industrial reforming or changing on the farm process. Water supply capacity is related on the reservoir volume, rain water collection or sea water desalination plants. The popular used package for system dynamics-STELLA, is used for context simulation.

Shortage index **SI** is adopted as the system performance index, which depends on the average shortage rate S_t.

$$SI = \frac{100}{N}\sum_{t=1}^{N}\left(\frac{S_t}{D_t}\right)^2$$

Where S_t means shortage at time t, D_t is the demands at time t. The shortage rate is defined as the average ratio of shortage volume and demand volume. Zero shortage index means there is no water deficit, and shortage index with 100% indicates most the severe water scarcity.

Fig -1 Areal view of Penghu

Fig-2 system design for simulation context

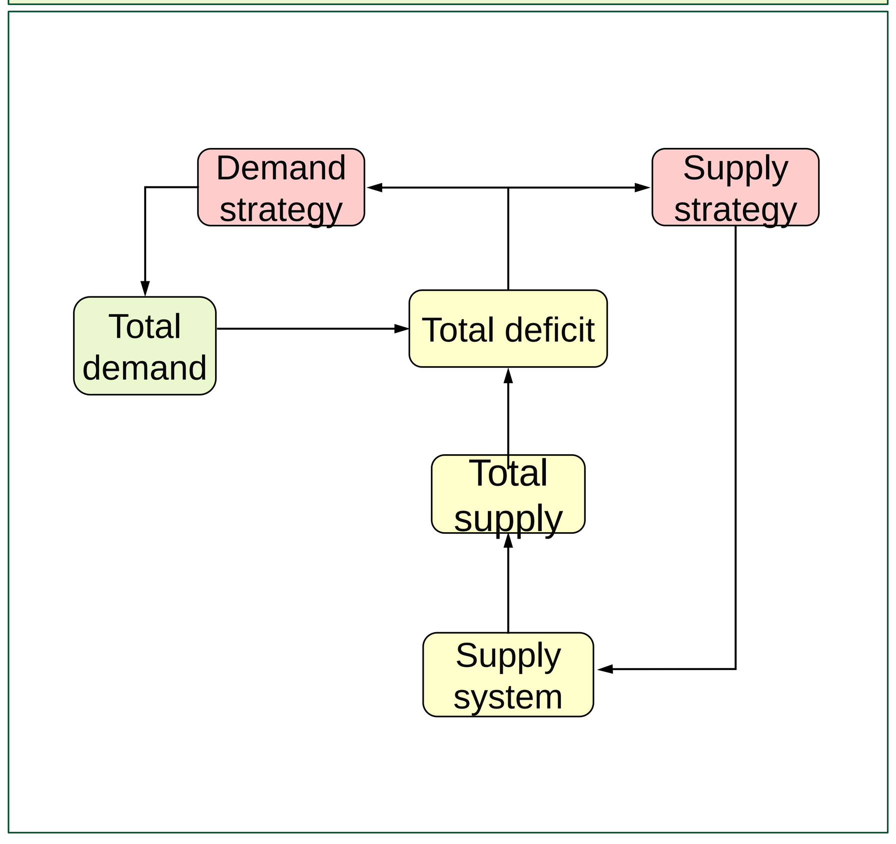


Fig -3 systematic diagram of supply units

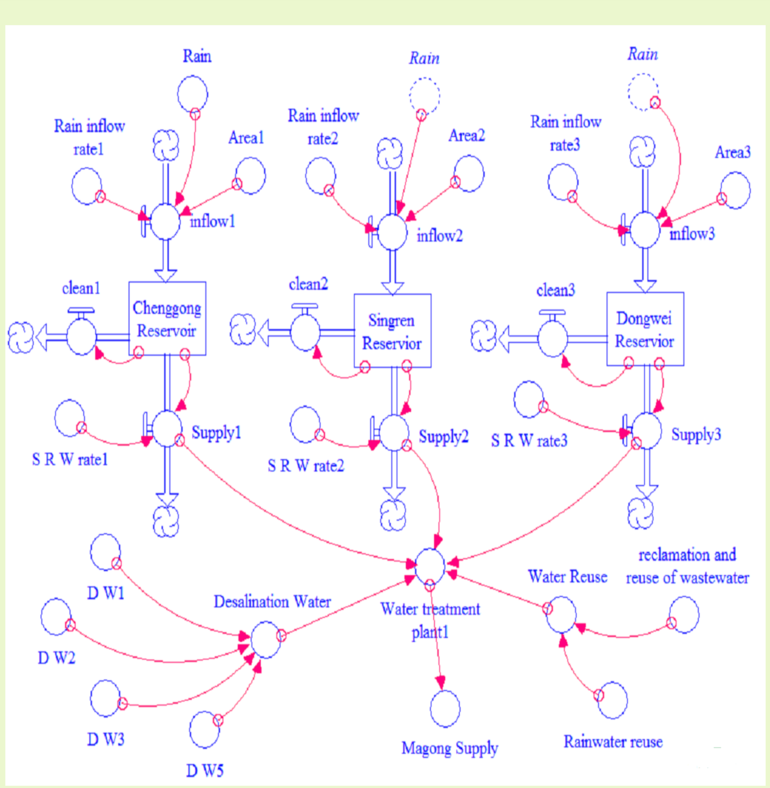
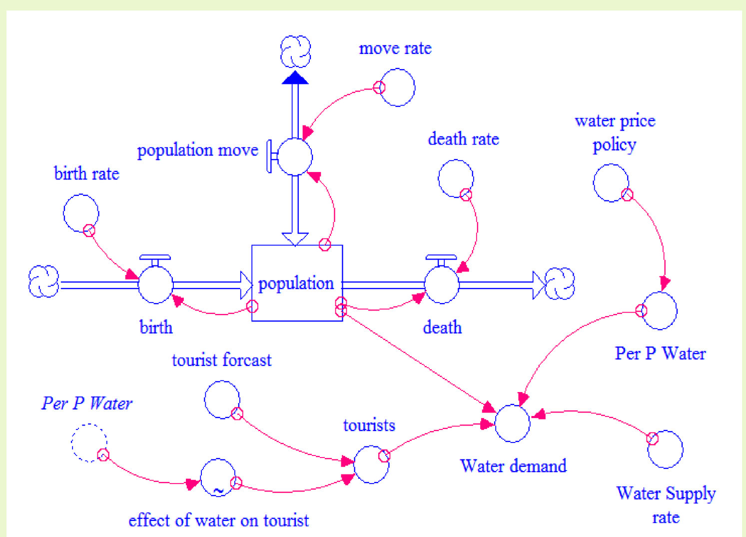


Fig -4 systematic diagram of demand units



Scenarios description

There are 3 alternatives for increasing the water supply capability. The first one is to expansion/enlarge operation capacity at the existed desalination plant. This is easier and less cost for decreasing the water deficit. The second choice is to build a new desalination plant near the existed one, which can join the existed supply piping system and solve the water deficit problem. Building a new plant takes time and cost high. The last alternative for increasing water supply is using the reclaim water. Reclaim water may be cheaper than the former two approaches but the reliability of reclaim water is lower than desalination method. As to the demand management, price policy is used to retrain the daily use of domestic water. These four alternatives combined into 8 contexts of water supply/demand management as shown at table-1.

Results and discussion

Under the various combinations of the context, we can find out the system performance via global shortage index. Results show that water shortage is found within each context. Some strategies make water shortage earlier due to rapid increasing in water demands.

Fig-6 shows that implementing claim water only can not meet the water demand within 5 years. If we adopt more alternatives water shortage situation comes later(Fig-7 the combination of expansion desalination plant, build new desalination plant and heightening the water price). In our study case, Penghu, the optimum strategy for water management is the combination of expanding desalination plant , building new desalination plant and increasing water price. This paper finds remodeling present desalination plant at Penghu is the most important factor for solving water shortage problems. While for a long run operation water usage per capita per day should be lower down through heightening water price.

References

1.Winz, I., Brierly, G., and Trousdale, Sam., The Use of System Dynamics Simulation in Water Resources Management, Water Resources Management, Vol. 23, 2009.
2.Huang Ming-Yang, Application of System Dynamics on the Allocation of Water Supply System - A Case Study in Penghu, Master thesis(in Chinese) , I-shou University, Taiwan, 2010.

Fig-5 performance sketch for shortage index

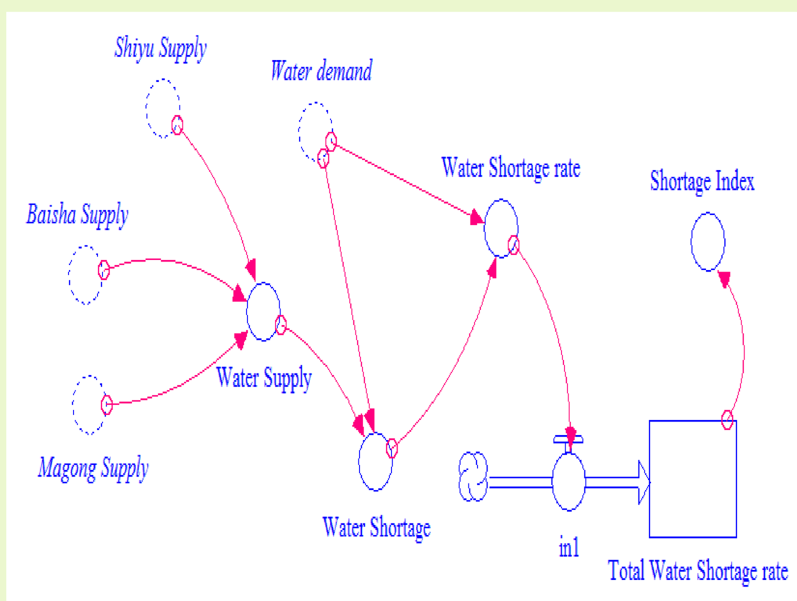


Fig-6 shortage condition via scenario-3

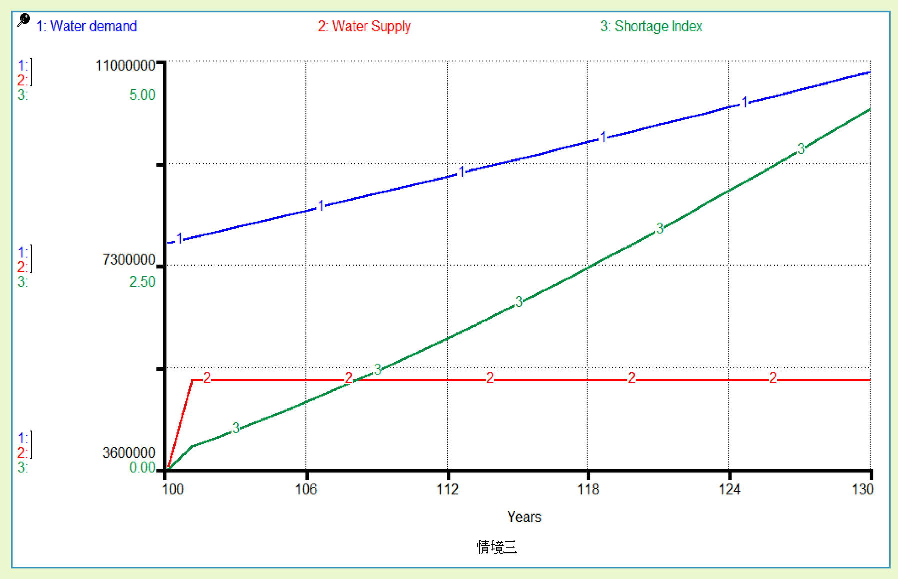


Fig-7 shortage condition via scenario-7

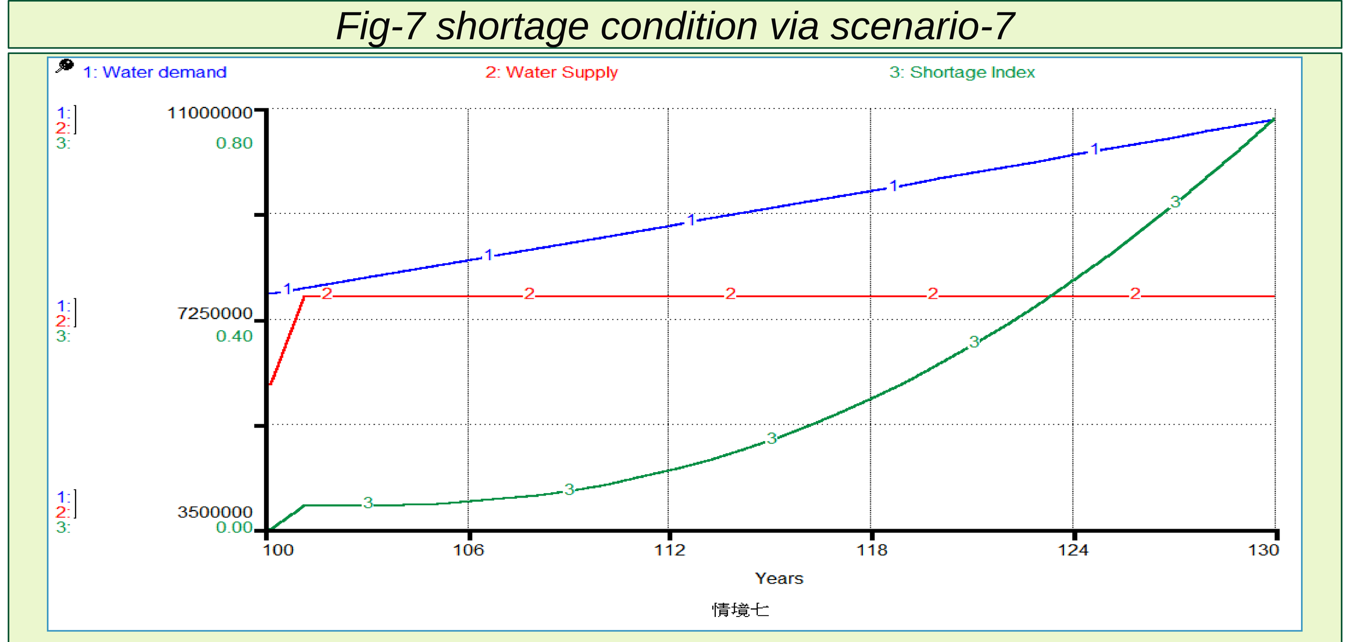


Table-1 scenarios for simulation

	supply			demand
code	A	B	C	D
Alternatives	Expansion the desalination plant	Build new desalination plant	Use of reclaim water	Decrease the demand by price increasing
Scenario 1	v			
Scenario 2			v	
Scenario 3				v
Scenario 4	v	v		
Scenario 5	v			v
Scenario 6			v	v
Scenario 7	v	v		v
Scenario 8	v	v	v	v